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(58) Field of search

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(54) **Compositions containing erythropoietin**

(57) Compositions for the treating the anemia of rheumatoid arthritis comprise human erythropoietin (EPO) in a parenterally acceptable vehicle. EPO may be extracted from human urine or can be prepared by expressing in a host cell the gene coding for the amino acid sequence of human EPO.

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SPECIFICATION

Pharmaceutical composition for the treatment of the anemia of rheumatoid arthritis

5 The present invention relates to a pharmaceutical composition for the treatment of the anemia of
rheumatoid arthritis that comprises a therapeutically effective amount of human erythropoietin (hereinafter
referred to as "human EPO") in a parenterally acceptable vehicle. 5

The term "human EPO" as used hereinafter means a polypeptide having the amino acid sequence
inherent in human beings, with or without sugar chains. Examples of the human EPO include one that is
10 derived from human urine (hereinafter referred to as "human urinary EPO"), one obtained by expressing in a
host cell the gene coding for the amino acid sequence of human EPO (this type of human EPO is hereinafter
referred to as "human rEPO"), one obtained from a tissue culture of human kidney cancer cells, and one
obtained by cultivating a hybridoma resulting from cell fusion of a human cell line having the ability to
15 produce human EPO. The term "erythropoietin" (hereinafter referred to as "EPO") will mean a trace
physiologically active substance that acts on erythroblastic stem cells present not only in humans but also in
other animals so as to accelerate the differentiation of such stems cells into mature erythrocytic cells, and
proliferation of the latter. While numerous studies on human urinary EPO have been reported, the
pharmaceutical utility of human EPO still remains unknown in many respects. 15

High incidence of anemia as one of the complications in patients with rheumatoid arthritis has been known
20 for many years (see, for example, Nilsson, F., *Acta. Med. Scand. Suppl.*, 270, 193 (1948), and Roberts, F. D. et
al.; *Blood*, 27, 470 (1983)), and severe anemia associated with rheumatoid arthritis is of particular clinical
concern in the treatment of the disease. 20

Many hypotheses have been proposed for explaining the mechanism behind the development of anemia,
and they include the blockade of iron in the reticuloendothelial system due to abnormal iron metabolism,
25 impaired iron release, spleen involvement, impaired EPO production, hemolysis, and disorders in
hemopoietic stem cells. The anemia of rheumatoid arthritis is believed to develop as a result of iron
deficiency in red blood cells due to abnormal iron metabolism because most causes of the anemia in
rheumatoid arthritis are of the type of normocytic hypochromemia, the average erythrocyte hemoglobin
levels are decreased, the number of erythroblasts in bone marrow are decreased, and the amount of free
30 protoporphyrin in erythrocytes are increased (see, for example, Wintrobe M.M; *Clinical Hematology*, 671,
Lea & Febiger, London (1974)). However, some researchers reported that there was no correlation between
the increase in the plasma EPO levels in patients with rheumatoid arthritis and the degree of anemia (see, for
example, Ward, H.P. et al., *J. Lab. Clin. Med.*, 74, 93 (1969); and Pavlovic-Kentera, v. et al, *Scand. J. Haematol*,
23, 141 (1979)). This observation suggests that impaired EPO production may also be involved in the anemia
35 of rheumatoid arthritis. However, in the absence of any observation demonstrating that patients with
rheumatoid arthritis suffer from disorders in the kidney, thyroid body or other EPO producing tissues, it is yet
to be established that impaired EPO production actually accompanies rheumatoid arthritis. Other causes that
have been proposed for explaining the fact that the plasma EPO levels in patients with rheumatoid arthritis
are not increased include bone marrow hyporesponsiveness to EPO and the possibility of production of an
40 EPO inhibitor. It has, therefore, been very doubtful that administration of human EPO to patients with the
anemia of rheumatoid arthritis is effective for the purpose of treating the disease. As already mentioned,
numerous papers exist that report the various functions of human urinary EPO but nobody has
demonstrated by in vivo experimentation with humans or animals that human urinary EPO and other types
of human EPO are effective as therapeutic agents for the treatment of anemia associated with rheumatoid
45 arthritis. 45

The present inventors prepared a highly pure form of human urinary EPO and they also obtained human
rEPO by expressing in a host cell the gene coding for the amino acid sequence of human EPO. Using these
two types of human EPO, the inventors studied their therapeutic effects for anemia in animal models
suffering from rheumatoid arthritis diseases. To their great surprise, these types of human EPO turned very
50 effective against the anemia, and therefore, the inventors concluded that they are useful as therapeutic
agents for the treatment of anemia of rheumatoid arthritis. The present invention has been accomplished on
the basis of this finding. 50

The principal object, therefore, of the present invention is to provide a novel pharmaceutical composition
for the treatment of anemia of rheumatoid arthritis that comprises a therapeutically effective amount of
55 human EPO in a parenterally acceptable vehicle. 55

The types of human EPO that are incorporated in the composition of the present invention as the active
ingredient may be prepared by a variety of means. For example, human urinary EPO may be extracted from
normal human urine or the urine of patients with hypoplastic anemia (T. Miyake et al., *J. B. C.*, 252, 5558
(1977); and J.P. Lewin et al., *J. Lab. Clin. Med.*, 66, 987 (1965)). Human rEPO may be prepared by genetic
60 engineering procedures comprising obtaining a messenger RNA (mRNA) corresponding to the amino acid
sequence of human EPO, preparing a recombinant DNA using the mRNA, and expressing the DNA gene in a
suitable host cell such as a bacterium (e.g. *E. coli*), a yeast, or a plant or animal cell line (see, for example,
Sylvia, L.H., *Proc. Natl. Acad. Sci., USA*, 81, 2708 (1984)). While various animal cell lines are available as host
cells, cultured cell lines derived from humans or mammalian animals are preferred and they include COS
65 cells, Chinese hamster ovary (CHO) cells, and mouse C-127 cells. Human EPO may also be prepared from, for 65

example, tissue cultures of human kidney cancer cells (Unexamined Published Japanese Patent Application No. 55790/1979), from human lymphoblastic cells having the human EPO producing ability (Unexamined Published Japanese Patent Application No. 40411/1982), and from a culture of the hybridoma obtained by cell fusion of a human cell line. Any of the types of human EPO that are prepared by these methods are useful in the present invention so long as they enable the proliferation of mature red blood cells having sufficient oxygen transport to be useful in the treatment of anemia of rheumatoid arthritis.

The human EPO present in the urine or the supernatant of culture obtained by the aforementioned methods may be further concentrated and purified by routine isolation and purification procedures such as, for example, precipitation with an organic solvent (e.g. benzoic acid, ethanol, acetone or tannic acid), salting out with ammonium sulfate, etc., dialysis by, for example, vacuum concentration, chromatographic techniques (e.g. gel permeation chromatography, ion-exchange chromatography and affinity chromatography), and electrophoretic techniques (e.g. isoelectric electrophoresis and gel electrophoresis). These isolation and purification procedures may be employed either independently or in combination.

The human EPO thus prepared may be stored either frozen or in a dehydrated state attained by freeze-drying, vacuum drying or other suitable methods. Alternatively, an aqueous solution containing the human EPO may be mixed with a water-soluble salt or a hydrophilic organic solvent to precipitate the active ingredient, which then is dehydrated for storage purposes. If desired, the human EPO may be dissolved in a suitable buffer solution and aseptically filtered such as through a Millipore filter to prepare an injection.

The pharmaceutical composition of the present invention for the treatment of anemia of rheumatoid arthritis may be mixed with conventional anemia treating agents such as chalybeates, vitamin B₁₂ and androgens, either in a dosage form or just before use. Illustrative chalybeates include dried ferrous sulfate, iron fumarate, iron dextran, iron gluconate, iron glucuronate and iron orotate.

The dosage and frequency of administration of the human EPO incorporated in the therapeutic composition of the present invention may be determined depending upon the condition of the patient under therapeutic regimen. In ordinary cases, a preparation containing 0.1 - 500 µg, preferably 5 - 100 µg, of human EPO may be administered to an adult in 1 - 7 doses for one week, assuming a human erythropoietin activity of 9×10^4 units per mg.

The pharmaceutical composition of the present invention for the treatment of anemia of rheumatoid arthritis may contain a stabilizer selected from among polyethylene glycol, proteins, sugars, amino acids, inorganic salts, organic salts and sulfur-containing reducing agents. These stabilizers may be employed either individually or in combination. They are preferably incorporated in the composition of the present invention in an amount ranging from 0.11 to 10,000 parts by weight per part by weight of human EPO. If two or more stabilizers are used, it suffices that the total of their amounts is within the range specified above. These stabilizers are used in the form of an aqueous solution containing a corresponding amount of a specific stabilizer to provide the appropriate concentration and pH. This aqueous solution is adjusted to have an osmotic pressure ratio of 0.1 - 3.0, preferably 0.8 - 1.2. The pH of the aqueous solution is adjusted to a value between 5.0 and 9.0, preferably between 6 and 8.

The composition of the present invention may be prepared in a dosage form in the presence of an adsorption preventing agent.

Reference Example 1: Preparation of human urinary EPO

Step (1): Partial purification from human urine

Urine from patients with hypoplastic anemia was subjected to the procedures of T. Miyake et al. (J. B. C., 52, 5558 (1977)); viz., 1) deionization on a Sephadex G50 column, 2) adsorption on DEAE-cellulose in a batch system, 3) precipitation with ethanol, and 4) chromatography on a DEAE-agarose column. By these procedures, a partially purified form of human urinary EPO was obtained.

Step (2): Reverse phase chromatography

The partially purified human urinary EPO was dissolved in a 0.1% trifluoroacetic acid (Aldrich Chemical Co., Inc.) solution containing 24% propanol (Wako Pure Chemical Industries, Ltd.) and the solution was subjected to purification by HPLC with Hitachi Model 638-50. Absorption in the ultraviolet range at 280 nm and 220 nm was used as an indicator.

The so prepared sample was loaded onto a YMC-C8 column (6 mm x 30 cm, product of Yamamura Chemical Co., Ltd.) equilibrated with a 0.1% trifluoroacetic acid solution containing 24% n-propanol, and the column was eluted with the same equilibrating solution. After the unadsorbed fractions were eluted, the concentration of n-propanol was increased to 26% for eluting the active fractions. The fractions containing the EPO activity were collected and concentrated to a volume of 0.1 - 0.2 ml by ultrafiltration using Centricon-100 (trade name of Amicon).

Step (3): High-performance molecular sieve chromatography

The concentrated sample was loaded onto a TSK -G300 SW column (7.8 mm x 60 cm, product of Toyo Soda Manufacturing Co., Ltd.) equilibrated with a 0.1% TFA solution containing 26% n-propanol, and the column was eluted with the same equilibrating solution. Peaks having the EPO activity were obtained at positions corresponding to molecular weights of 25,000 - 30,000. These active fractions were collected and freeze-dried. The fractions had a specific activity of about 9×10^4 units/mg.

The specific activities of the samples prepared in the respective steps (1) to (3) are listed in Table I.

TABLE I

5	<i>Step</i>	<i>Specific activity (U/mg)</i>	5
	(1) partial purification	600	
	(2) reverse phase chromatography	10,000	
10	(3) high-performance molecular sieve chromatography	90,000	10

Assay method: In accordance with the method of N.N. Iscove et al., J. Cell. Physiol., 83, 309 (1974).

Reference Example 2: Preparation of human rEPO derived from CHO cells

15 A plasmid incorporating the gene coding for the amino acid sequence of human EPO was expressed in Chinese hamster ovary cells (CHO cells) to produce human rEPO. The procedures employed are specifically described in Japanese Patent Application No. 281862/1984 (filed December 27, 1984), entitled "Vector harboring accessory DNA for the transformation of eucaryotic cells". A summary of the procedures is given below.

20 The DNA from a lambda HEPOFL 13 clone incorporating the gene coding for the amino acid sequence of human EPO derived from fetal human liver cells was digested with EcoRI, and the recovered small EcoRI fragment harboring the gene coding for the amino acid sequence of human EPO was inserted into the EcoRI site of plasmid RKI-4. The plasmid then was incorporated into DHFR-deficient CHO cells so as to transform them. The transformed CHO cells were cultured in an alpha-medium deficient of nucleic acids. Cells harboring at least one DHFR gene were selected and employed in the production of human rEPO, with the concentration of methotrexate in the medium being increased incrementally. The human rEPO in the supernatant of the finally obtained culture had an activity of 20 units/ml.

25 The CHO cells were cultivated in a serum-free liquid culture medium for 3 days and pure human rEPO was isolated by the procedures employed in the preparation of pure human urinary EPO. The so obtained human rEPO was found to have an activity of 6,600 units/ml as measured by the method of Krystal et al. (J. Lab. Clin. Med., 97, 144 (1981)). SDS-polyacrylamide gel electrophoresis showed that this human rEPO was comprised of a single protein band. The human rEPO was mixed with 0.1% BSA and dialyzed against physiological saline to prepare samples for use in subsequent experiments.

35 *Experiments: Therapeutic effects of human rEPO for the treatment of anemia in adjuvant-initiated arthritis rats*

1. Preparation of adjuvant-induced arthritis rats

40 To the tails of 8-week-old female LEW/Crj rats (bought from Japan Charles River Co., Ltd.), 0.05 ml of an adjuvant (50 mg/ml of strain Aoyama B) was administered subcutaneously. At 27 days of injection, the development of arthritis was confirmed in the adjuvant-treated rats, which then were subjected to the measurement of the following erythrocyte parameters.

Parameters

45	1) Hemoglobin	: Blood samples withdrawn from the eye were subjected to spectrophotometry on RaBA Super sold from Chugai Pharmaceutical Co., Ltd.	45
50	2) Hematocrit	: Blood samples were withdrawn from the eye through a hematocrit tube and the hematocrit was measured by routine procedures.	50
55	3) Erythrocyte count	: Blood samples withdrawn from the eye were diluted with ISOTON (trade name of Coulter Electronics, Inc.) and erythrocyte counting was performed with a Coulter counter Model ZBI.	55

60 The erythrocyte parameters in the adjuvant-treated rats as compared with the normal values are summarized in Table II.

TABLE II

	Parameter	Normal rats	Treated rats	
5	Hematocrit (%)	46.4 ± 0.74	41.9 ± 0.46**	5
	Hemoglobin (g/dl)	14.9 ± 0.27	12.2 ± 0.40**	
	Erythrocyte count (x10 ⁴)/mm ³)	860 ± 7	736 ± 10**	
			**P < 0.01	

10 (Assayed at 27 days of adjuvant sensitization each group consisting of 4 rats)
 As Table II shows, all of the erythrocyte parameters in the adjuvant-treated rats differed significantly from those in the normal rats, and the rats were found to be in the anemic state.

15 2. *Therapeutic effects of human urinary EPO for the treatment of anemia in the adjuvant-treated rats*
 Each of the adjuvant-treated rats prepared in 1 was injected intraperitoneally with human urinary EPO (25 units/rat/day) for seven consecutive days starting at 18 days of adjuvant treatment. The treated groups were compared with the control group for the erythrocyte parameters as shown in Table III.

TABLE III

	Parameters	Control	EPO treated rats	
	Hematocrit (%)	43.2 ± 0.51	51.1 ± 0.54**	
25	Hemoglobin (g/dl)	11.8 ± 0.27	14.4 ± 0.40**	25
	Erythrocyte count (x10 ⁴ /mm ³)	705 ± 18.6	829 ± 20.0**	
			**P < 0.01	

30 (Seven rats per group)
 3. *Therapeutic effects of CHO cell derived human rEPO for the treatment of anemia in adjuvant-treated rats*
 Each of the adjuvant-treated rats prepared in 1 was injected intraperitoneally with CHO cell derived human rEPO (10 units/rat/day) for seven consecutive days starting at 18 days of adjuvant treatment. The treated groups were compared with the control group for the erythrocyte parameters and the results are shown in Table IV.

TABLE IV

	Parameters	Control	EPO treated rats	
40	Hematocrit (%)	41.9 ± 0.28	46.8 ± 0.53**	40
	Hemoglobin (g/dl)	11.9 ± 0.33	14.7 ± 0.16**	
45	Erythrocyte count (x10 ⁴ /mm ³)	715 ± 6.7	837 ± 17.0**	45
			**P < 0.01	

(Seven rats per group)
 As Table III and IV show, all of the erythrocyte parameters in the group of rats treated with human EPO were significantly improved as compared with the control group. It is therefore concluded that the human EPO prepared in accordance with the present invention is effective for the treatment of anemia associated with rheumatoid arthritis. The two types of human EPO had no toxicity under the experimental conditions used.

55 The following examples are provided for the purpose of further illustrating the present invention but are by no means taken as limiting.

Example 1

A solution was aseptically prepared from the formulation indicated below.

	Ingredients	Amount (parts by weight)	
60	CHO cell derived human rEPO	1	60
	Human serum albumin	100	
	Distilled water for injection	to make 100,000	

The solution was distributed among vials and freeze-dried, followed by the sealing of the vials.

Example 2

Freeze-dried preparations were made as in Example 1 except that the human serum albumin was replaced
5 by 100 parts by weight of dextran 40. 5

Example 3

An aqueous solution containing mannitol (5 g), human urinary EPO (1 mg), human serum albumin (100
mg), sodium acetyltryptophan (2.154 mg) and sodium caprylate (1.33 mg) in 100 ml was prepared
10 aseptically. Small portions (1 ml) of the solution were put into vials and freeze-dried, followed by the sealing
of the vials. 10

Example 4

An aqueous solution containing human urinary EPO (1mg), polyethylene glycol 4000 (500 mg), ethylene
15 oxidepropylene oxide copolymer (30 mg) and sodium chloride (800 mg) in 100 ml of a 0.05 M phosphate
buffer solution (pH 7.0) was prepared aseptically. Small portions (1 ml) of the solution were put into
ampules, which then were sealed by fusion. 15

Example 5

An aqueous solution containing CHO cell derived human rEPO (0.5 mg), glycine (1 g) and sorbitol (1 g) in
20 50 ml of a 0.05 M phosphate buffer solution (pH 7.0) was prepared aseptically. Small portions (0.5 ml) of the
solution were put into vials and freeze-dried, followed by the sealing of the vials. A 0.1% aqueous solution of
methyl cellulose was also prepared aseptically and 1-ml portions of the solution were put into ampules for
making solubilizing media. 20

Example 6

An aqueous solution containing human urinary EPO (1 mg), human serum albumin (50 mg) and mannitol
(500 mg) in 100 ml was prepared aseptically. Small portions (1 ml) of the solution were put into vials and
freeze-dried, followed by the sealing of the vials. An aqueous solution containing ferric gluconate (3 g) and
30 NaCl (2.7 g) in 300 ml was also prepared aseptically, and 3-ml portions of this solution were put into ampules
which then were sealed by fusion. The content of one vial was transferred into one ampule and a complete
solution was obtained by thorough mixing. The solution was injected intravenously over time (2-3 minutes). 30

CLAIMS

- 35 1. A pharmaceutical composition for the treatment of the anemia of rheumatoid arthritis comprising a
therapeutically effective amount of human erythropoietin in a parenterally acceptable vehicle.
2. A pharmaceutical composition according to claim 1 wherein the human erythropoietin is derived from
human urine.
- 40 3. A pharmaceutical composition according to claim 1 wherein the human erythropoietin is obtained by
expressing in a host cell the gene coding for the amino acid sequence of human erythropoietin.
4. A pharmaceutical composition according to claim 3 wherein the host cell is an E. coli cell, a yeast cell, a
plant cell line or an animal cell line.
5. A pharmaceutical composition according to claim 3 wherein the host cell is a Chinese hamster ovary
45 cell. 45
6. A pharmaceutical composition according to claim 3 wherein the host cell is a COS cell.
7. For use in the treatment of the anemia of rheumatoid arthritis, human erythropoietin.